



Radioactivity in the Risø District January-June 2015

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Radioactivity in the Risø District January-June 2015

The cover design features a large rectangular area on the left with a grid of squares in shades of blue and green. A vertical red bar is positioned on the left side of this grid, containing the text 'DTU Nutech Report' in white. To the right of the grid is a solid light green rectangular area.

DTU Nutech Report

Sven P. Nielsen, Kasper G. Andersson and Arne Miller
DTU-Nutech-12(EN)
December 2015

DTU Nutech
Center for Nuclear Technologies



Author: Sven P. Nielsen, Kasper G. Andersson and Arne Miller
Title: Radioactivity in the Risø District January-June 2015
Center for Nuclear Technologies

DTU-Nutech-12(EN)
December 2015

Abstract (max. 2000 char.): The environmental surveillance of the Risø environment was continued in January-June 2015. The mean concentrations in air were: $0.23 \pm 0.18 \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.19 \pm 0.91 \text{ mBq m}^{-3}$ of ^7Be and $0.13 \pm 0.05 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 S.D.). The depositions by precipitation at Risø in the first half of 2015 were: $0.054 \pm 0.015 \text{ Bq m}^{-2}$ of ^{137}Cs , $433 \pm 43 \text{ Bq m}^{-2}$ of ^7Be , $22.5 \pm 4.5 \text{ Bq m}^{-2}$ of ^{210}Pb and $< 0.5 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as 63 nSv h^{-1} compared with $56 \pm 3 \text{ nSv h}^{-1}$ (± 1 S.D.) in the four zones around Risø.

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INTRODUCTION

A specific monitoring programme in the vicinity of the nuclear installations at the Risø site is carried out by DTU Nutech on behalf of and as a contractor to Danish Decommissioning (DD). This report presents the analytical results of the monitoring and sampling carried out in the period January-June 2015. The materials and methods used in connection with the monitoring programme are described in pages 25-26.

Table 1. Radionuclides in ground level air collected at Risø (cf. Figs. 1, 1.1 and 1.2), January - June 2015 (Unit: $\mu\text{Bq m}^{-3}$)

Date	^7Be	^{137}Cs	^{210}Pb
30-Dec-14 – 06-Jan-15	1860(10%)*	0.159(12%)	84(10%)
06-Jan-15 – 12-Jan-15	1248(10%)	0.083(13%)	21(10%)
12-Jan-15 – 19-Jan-15	2001(10%)	0.138(11%)	51(10%)
19-Jan-15 – 26-Jan-15	1208(10%)	0.417(10%)	133(10%)
26-Jan-15 – 02-Feb-15	1322(10%)	0.196(10%)	64(10%)
02-Feb-15 – 09-Feb-15	754(10%)	0.328(10%)	165(10%)
09-Feb-15 – 16-Feb-15	1509(10%)	0.182(11%)	160(10%)
16-Feb-15 – 23-Feb-15	1634(10%)	0.469(10%)	158(10%)
23-Feb-15 – 02-Mar-15	1718(10%)	0.203(10%)	76(10%)
02-Mar-15 – 09-Mar-15	3705(10%)	0.176(11%)	124(10%)
09-Mar-15 – 16-Mar-15	1141(10%)	0.348(10%)	125(10%)
16-Mar-15 – 23-Mar-15	2508(10%)	0.990(10%)	190(10%)
23-Mar-15 – 30-Mar-15	1327(10%)	0.280(10%)	63(10%)
30-Mar-15 – 07-Apr-15	1775(10%)	0.200(13%)	101(10%)
07-Apr-15 – 13-Apr-15	4031(10%)	0.250(12%)	114(10%)
13-Apr-15 – 20-Apr-15	1881(10%)	0.168(11%)	134(10%)
20-Apr-15 – 27-Apr-15	4299(10%)	0.243(13%)	233(10%)
27-Apr-15 – 04-May-15	2779(10%)	0.140(12%)	105(10%)
04-May-15 – 11-May-15	2298(10%)	0.116(12%)	100(10%)
11-May-15 – 18-May-15	2632(10%)	0.101(12%)	101(10%)
18-May-15 – 26-May-15	2259(10%)	0.129(14%)	132(10%)
26-May-15 – 01-Jun-15	1928(10%)	0.130(13%)	104(10%)
01-Jun-15 – 08-Jun-15	3652(10%)	0.143(12%)	195(10%)
08-Jun-15 – 15-Jun-15	3025(10%)	0.150(12%)	216(10%)
15-Jun-15 – 22-Jun-15	2270(10%)	0.098(13%)	150(10%)
22-Jun-15 – 29-Jun-15	2189(10%)	0.107(13%)	139(10%)
Mean	2191	0.229	125
SD	912	0.181	50

*Figures in brackets are relative standard uncertainties

Table 2.1. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), January - June 2015. (Unit: Bq m⁻³)

Month	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
January	1077(10%)*	0.105(34%)	79(18%)
February	1340(10%)	0.278(41%)	113(12%)
March	1612(10%)	0.324(23%)	131(10%)
April	1081(10%)	0.251(25%)	98(10%)
May	1987(10%)	0.475(31%)	127(31%)
June	1506(10%)	0.334(14%)	110(17%)

*Figures in brackets are relative standard uncertainties

Table 2.2. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), January - June 2015. (Unit: Bq m⁻²)

Month	Precipitation (m)	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
January	0.069(10%)*	74.6(10%)	0.0072(35%)	5.5(21%)
February	0.024(10%)	32.2(10%)	0.0067(42%)	2.7(16%)
March	0.022(10%)	35.4(10%)	0.0042(25%)	2.8(14%)
April	0.025(10%)	27.3(10%)	0.0063(27%)	2.5(14%)
May	0.028(10%)	55.6(10%)	0.0133(33%)	3.6(32%)
June	0.049(10%)	73.7(10%)	0.0164(17%)	5.4(20%)
Sum	0.217(5%)	432.6(5%)	0.0541(12%)	22.5(9%)

*Figures in brackets are relative standard uncertainties

Table 2.3. Tritium in precipitation collected at Risø (cf. Figs. 1, 2.3.1 and 2.3.2). January - June 2015. (Unit: kBq m⁻³)

Month	10 m ² rain collector*
January	< 2.1
February	2.9(28%) ^b
March	2.5(32%)
April	3.0(24%)
May	2.3(33%)
June	- ^a
Double determinations*.	

^a Precipitation sample collected, but not yet analysed, due to illness of key staff.

^b Figures in brackets are relative standard uncertainties

Table 2.4. Tritium in precipitation collected at Risø (cf. Fig. 1). January - June 2015. (Unit: kBq m⁻²)

Month	Precipitation (m)	10 m ² rain collector
January	0.069(10%) ^a	< 0.145
February	0.024(10%)	0.070(30%)
March	0.022(10%)	0.055(33%)
April	0.025(10%)	0.075(26%)
May	0.028(10%)	0.064(35%)
June	0.049(10%)	- ^a
Sum	0.217(5%)	

^a Figures in brackets are relative standard uncertainties

Table 3.1. Radionuclides in sediment samples collected at Bolund in Roskilde Fjord.(cf. Fig. 3.1) January - June 2015. (Unit: Bq kg⁻¹ dry)

No samples in this period.

Table 4.1. Radionuclides in seawater collected in Roskilde Fjord (cf. Fig. 4.1) January - June 2015. (Unit: Bq m⁻³)

No samples in this period.

Table 4.2. Tritium in seawater collected in Roskilde Fjord (Risø pier) (cf. Fig. 4.2) January - June 2015.

Month	kBq m ⁻³
March	< 2.1 *
June	- ^a

* Double determinations

^a Seawater has been sampled also in June 2015, but not yet analysed, due to illness of key staff.

Table 5.1. Radionuclides in grass (* snow) collected at Risø near the Waste Treatment Station, location I P3, Fig. 1, January - June 2015. (**Measured on bulked ash samples)

Week no. or month	Date	K (g kg ⁻¹ fresh)	¹³⁷ Cs (Bq kg ⁻¹ fresh)	¹³⁷ Cs (Bq m ⁻²)
1	1 January	<2.0	<0.2	
3	12 January	2.6(10%) ^a	0.7(30%)	
5	26 January	<0.06	<0.2	
7	9 February	3.4(11%)	<0.6	
9	23 February	2.7(11%)	<0.3	
11	9 March	4.9(11%)	<0.7	
13	23 March	5.4(10%)	<0.5	
15	7 April	6.1(10%)	1.1(30%)	
17	20 April	5.4(10%)	<0.4	
19	4 May	4.7(10%)	<0.5	
21	18 May	2.8(10%)	<0.3	
23	1 June	5.0(10%)	<0.5	
25	15 June	3.8(10%)	0.4(35%)	
**January			0.465(12%)	0.221(15%)
**February			0.265(12%)	0.063(15%)
**March			0.306(13%)	0.042(16%)
**April			0.429(12%)	0.112(15%)
**May			0.176(16%)	0.072(19%)
**June			0.296(14%)	0.079(17%)

^a Figures in brackets are relative standard uncertainties

Table 5.2. Radionuclides in Fucus vesiculosus collected at Bolund in Roskilde Fjord. January - June 2015. (Unit: Bq kg⁻¹ dry)

No samples in this period.

Table 7.1. Waste water collected at Risø (cf. Fig. 1), January - June 2015.

Week number	eqv. mg KCl l ⁻¹	¹³⁷ Cs (Bq m ⁻³)	¹³¹ I (Bq m ⁻³)	²²⁶ Ra (Bq m ⁻³)
1	34(12%)*	<72	<121	<141
2	34(13%)	<72	<83	<143
3	50(11%)	<68	<67	<139
4	66(10%)	<122	<130	<260
5	30(12%)	<72	<72	<147
6	25(13%)	<126	<140	<266
7	40(14%)	<70	<69	<147
8	44(12%)	<118	<148	<250
9	55(11%)	<111	<147	<258
10	74(11%)	<84	<81	<164
11	59(11%)	<72	<72	<162
12	61(12%)	<119	<146	<263
13	57(12%)	<81	<73	<142
14	54(11%)	<121	<936 ¹	<270
15	68(10%)	<126	<523	<276
16	78(12%)	<120	<526	<303
17	88(11%)	<123	<526	<298
18	92(11%)	<125	<301	<300
19	89(11%)	<118	<220	<274
20	161(10%)	<136	1105(18%) ²	<325
21	138(11%)	<126	<130	<295
22	115(10%)	805(19%) ³	<140	<296
23	132(10%)	631(17%)	<78	<155
24	111(10%)	457(21%)	<102	<211
25	112(10%)	400(20%)	<72	<139
26	123(10%)	334(32%)	<141	<314
Mean	76.5	< 185	<244	<228
SD	37	206		

* Figures in brackets are relative standard uncertainties

¹ Sample measurements for week 14 and to a lesser degree for the following weeks were carried out with a delay, which considerably increased the detection limit of short lived ¹³¹I. The delay was due to extensive laboratory restoration work making analyses impossible for some time.

² The enhanced level of ¹³¹I measured in week 20 coincides with measurement at DTU Nutech of comparatively high levels of ¹³¹I in waste water (50 kBq/l) and sludge (600 Bq/g) from Herlev Hospital.

³ The reason for the enhanced level is not known

Table 8.1. Background dose rates around the border of Risø (cf. Fig. 8.1) measured with thermoluminescence dosimeters (TLD) in the period November 2014 – April 2015. (Results are normalized to nSv h^{-1})

Location	nSv h^{-1} ^a
1	50(10%) ^a
2	49(10%)
3	—*
4	58(10%)
5	59(10%)
6	62(10%)
Mean	56(5%)

*The dosimeter has been lost during the exposure period

^a Figures in brackets in Table 8.1 and 8.2 are relative standard uncertainties

Table 8.2. Background dose rates around Risø (cf. Fig. 8.2 and Fig. 1) measured with thermoluminescence dosimeters (TLD) in the period November 2014– April 2015. (Results are normalized to nSv h^{-1}),

Risø zone	Location	nSv h^{-1} ^a
I	1	48(10%) ^a
I	2	56(10%)
I	3	85(10%)
I	4	58(10%)
I	5	67(10%)
Mean		63(5%)
II	P1	59(10%)
II	P2	62(10%)
II	P3	46(10%)
II	P4	66(10%)
Mean		58(5%)
III	P1	48(10%)
III	P2	69(10%)
III	P3	55(10%)
Mean		57(6%)
IV	P1	45(10%)
IV	P2	47(10%)
IV	P3	60(10%)
IV	P4	55(10%)
IV	P5	54(10%)
IV	P6	47(10%)
IV	P7	65(10%)
Mean		53(4%)
V	P1	58(10%)
V	P2	69(10%)
V	P3	70(10%)
V	P4	47(10%)
V	P5	55(10%)
V	P6	41(10%)
V	P7	53(10%)
V	P8	61(10%)
V	P9	52(10%)
V	P10	66(10%)
Mean		57(4%)

Table 8.3. Terrestrial dose rates at the Risø zones (cf. Fig. 8.2 and Fig. 1) January – June 2015. Measured with a NaI(Tl) detector. (Unit: nSv h⁻¹)

Risø zone	Location	October
I	P1	40(10%)
I	P2	51(10%)
I	P3	346(10%)
I	P4	45(10%)
I	P5	50(10%)
Mean		106(5%)
II	P1	44(10%)
II	P2	48(10%)
II	P3	40(10%)
II	P4	42(10%)
Mean		43(4%)
III	P1	46(10%)
III	P2	48(10%)
III	P3	51(10%)
Mean		48(6%)
IV	P1	35(10%)
IV	P2	43(10%)
IV	P3	43(10%)
IV	P4	48(10%)
IV	P5	31(10%)
IV	P6	44(10%)
IV	P7	53(10%)
Mean		42(4%)
V	P1	58(10%)
V	P2	57(10%)
V	P3	57(10%)
V	P4	48(10%)
V	P5	48(10%)
V	P6	70(10%)
V	P7	44(10%)
V	P7a	52(10%)
V	P8	45(10%)
V	P9	53(10%)
V	P10	39(10%)
Mean		52(4%)

Figures in brackets are relative standard uncertainties

The higher value of external radiation at location P3 in Risø zone I is caused by enhanced level of low-energy gamma radiation from the DD Waste Treatment Station, where barrels contain radioactive waste from, e.g., industry. The stored barrels are shielded on the sides, but not upwards, leading to increased contributions to dose rate from low-energy gamma radiation scattered in air. The NaI detector is particularly sensitive to low energy gamma radiation, which means that the dose rate is overestimated by about 40 % at this location.

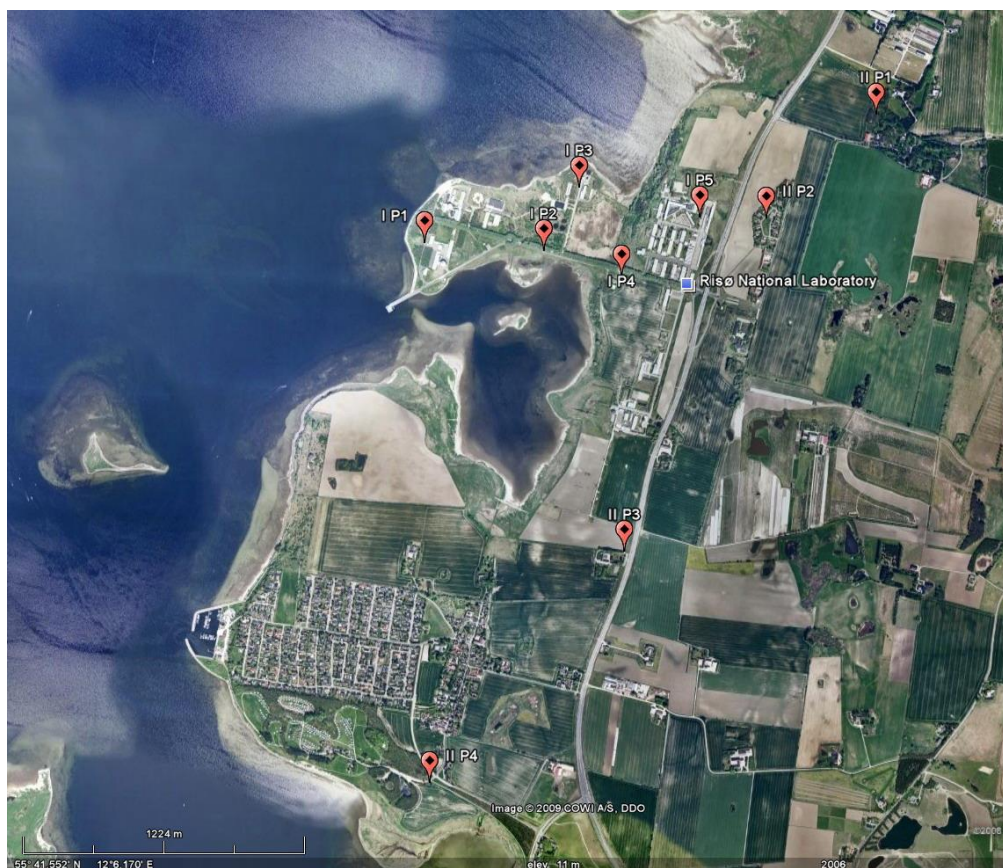


Fig. 1. Locations for measurements of gamma-background radiation Zone I and II (cf. Tables 8.2 and 8.3)

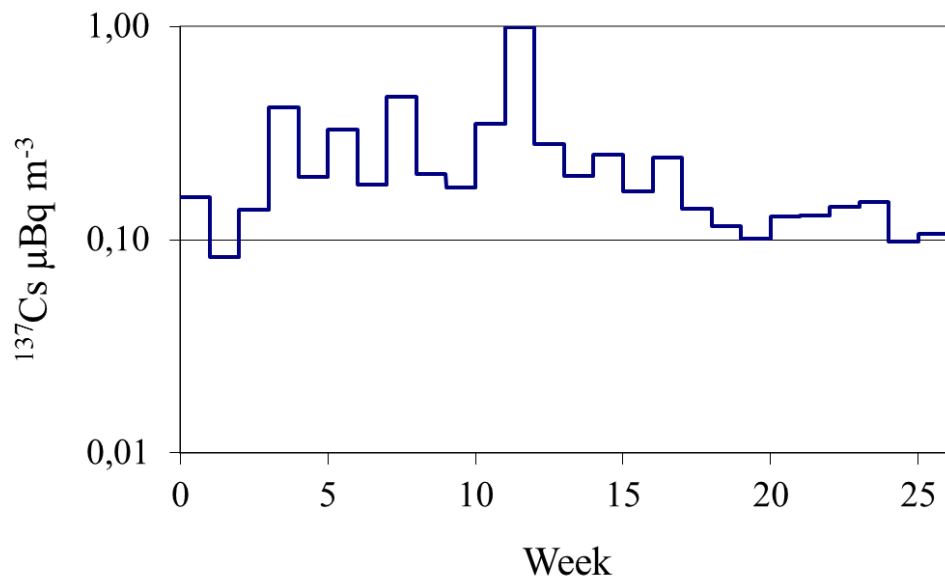


Fig. 1.1. Caesium-137 in ground level air collected at Risø in January-June 2015. (Unit: $\mu\text{Bq m}^{-3}$)

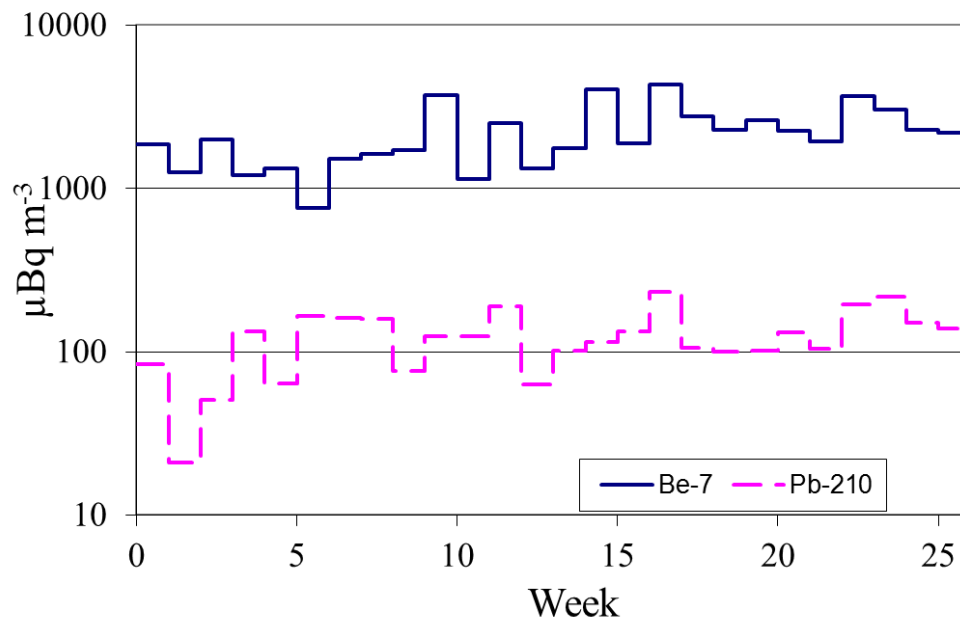


Fig. 1.2. Beryllium-7 and Lead-210 in ground level air collected at Risø in January-June 2015. (Unit: $\mu\text{Bq m}^{-3}$)

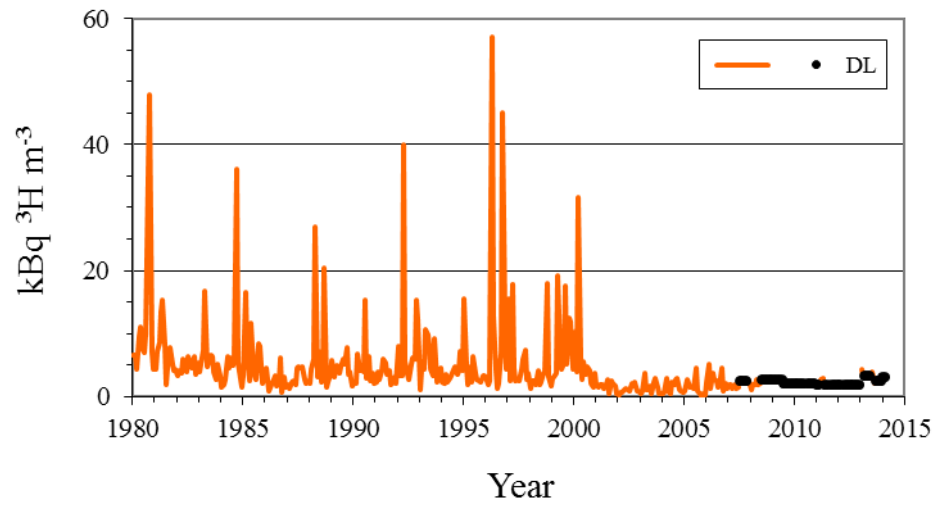


Fig. 2.3.1. Tritium in precipitation collected at Risø (1 m² rain collector) 1980 - 2013. (Unit: kBq m⁻³; DL = detection limit . This rain collector was taken out of operation in 2013.

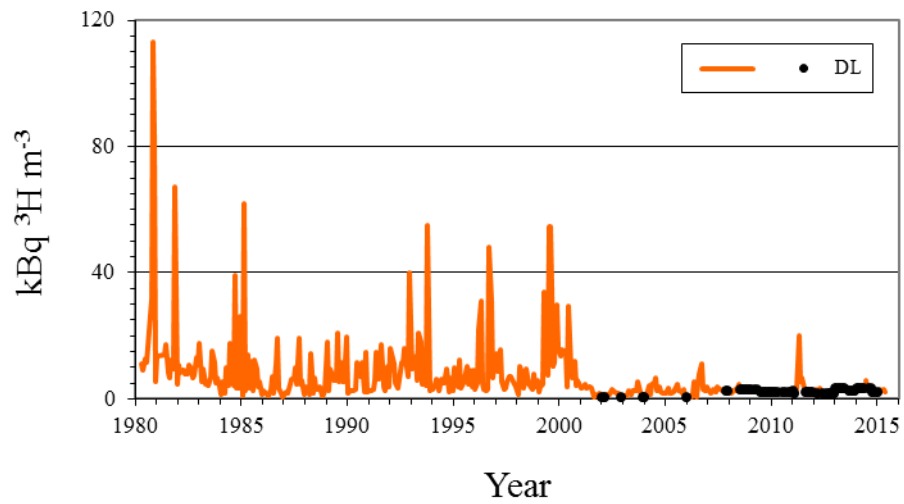


Fig. 2.3.2. Tritium in precipitation collected at Risø (10 m² rain collector) 1980 - 2015. (Unit: kBq m⁻³; DL = detection limit)

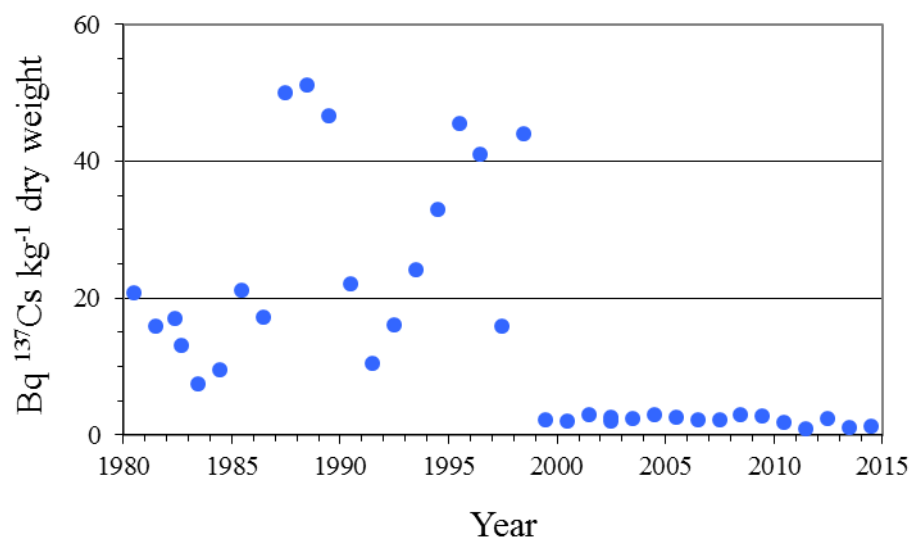


Fig. 3.1. Caesium-137 in sediment samples collected at Bolund in Roskilde Fjord. 1980 – 2015. (Unit: Bq kg^{-1} dry matter)

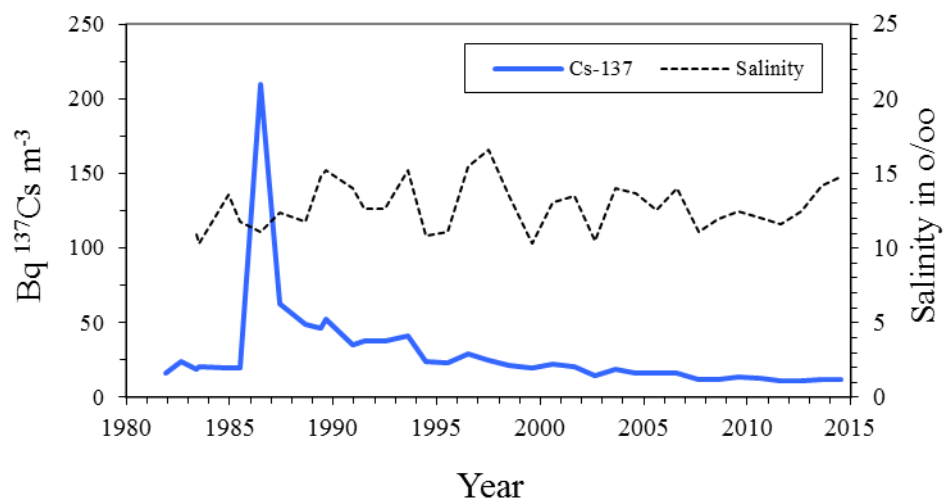


Fig. 4.1. Caesium-137 in seawater collected in Roskilde Fjord 1980 - 2015.
(Unit: $Bq\ m^{-3}$)

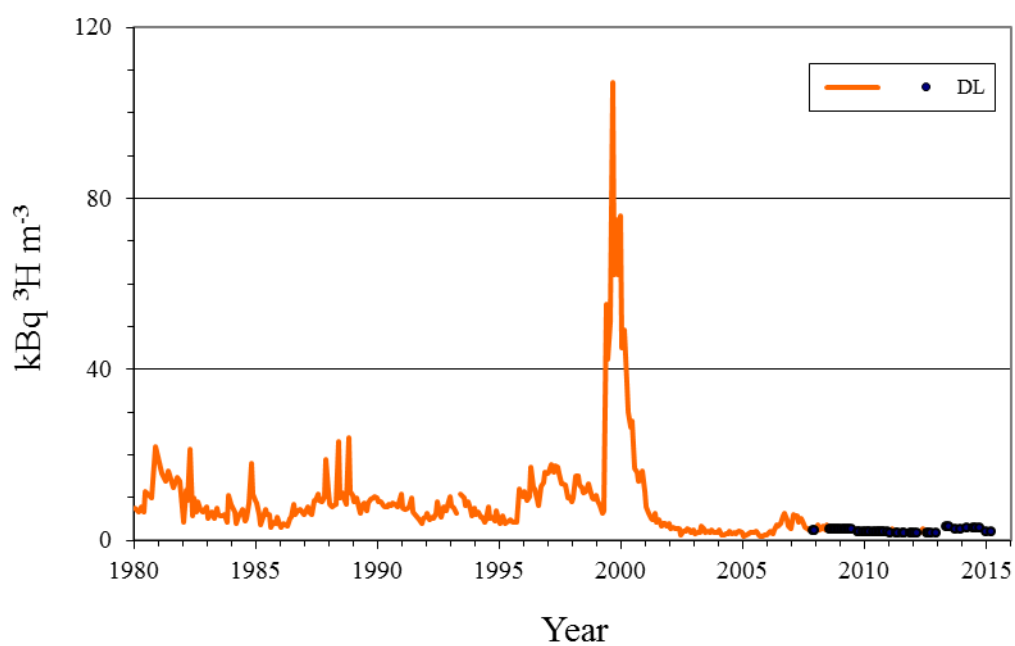
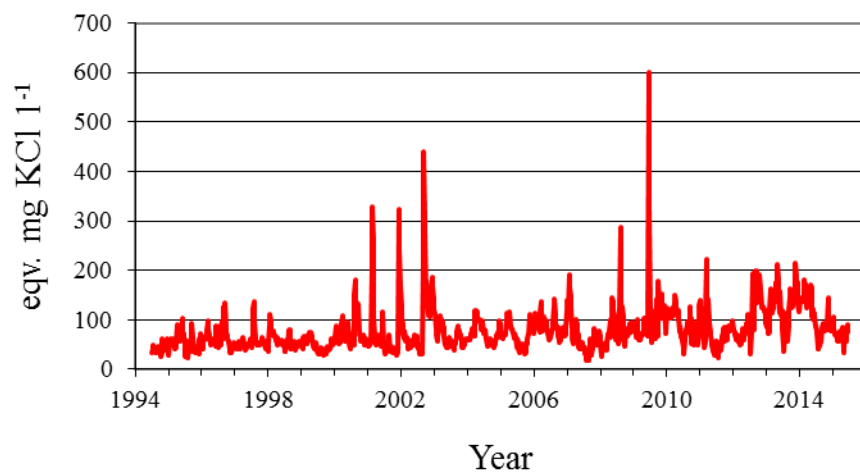


Fig. 4.2. Tritium in seawater collected in Roskilde Fjord 1980 - 2015.
(Unit: $kBq\ m^{-3}$; DL = detection limit)



*Fig. 7.1. Total-beta radioactivity in waste water collected at Risø 1994 - 2015.
(Unit: eqv. mg KCl l⁻¹)*

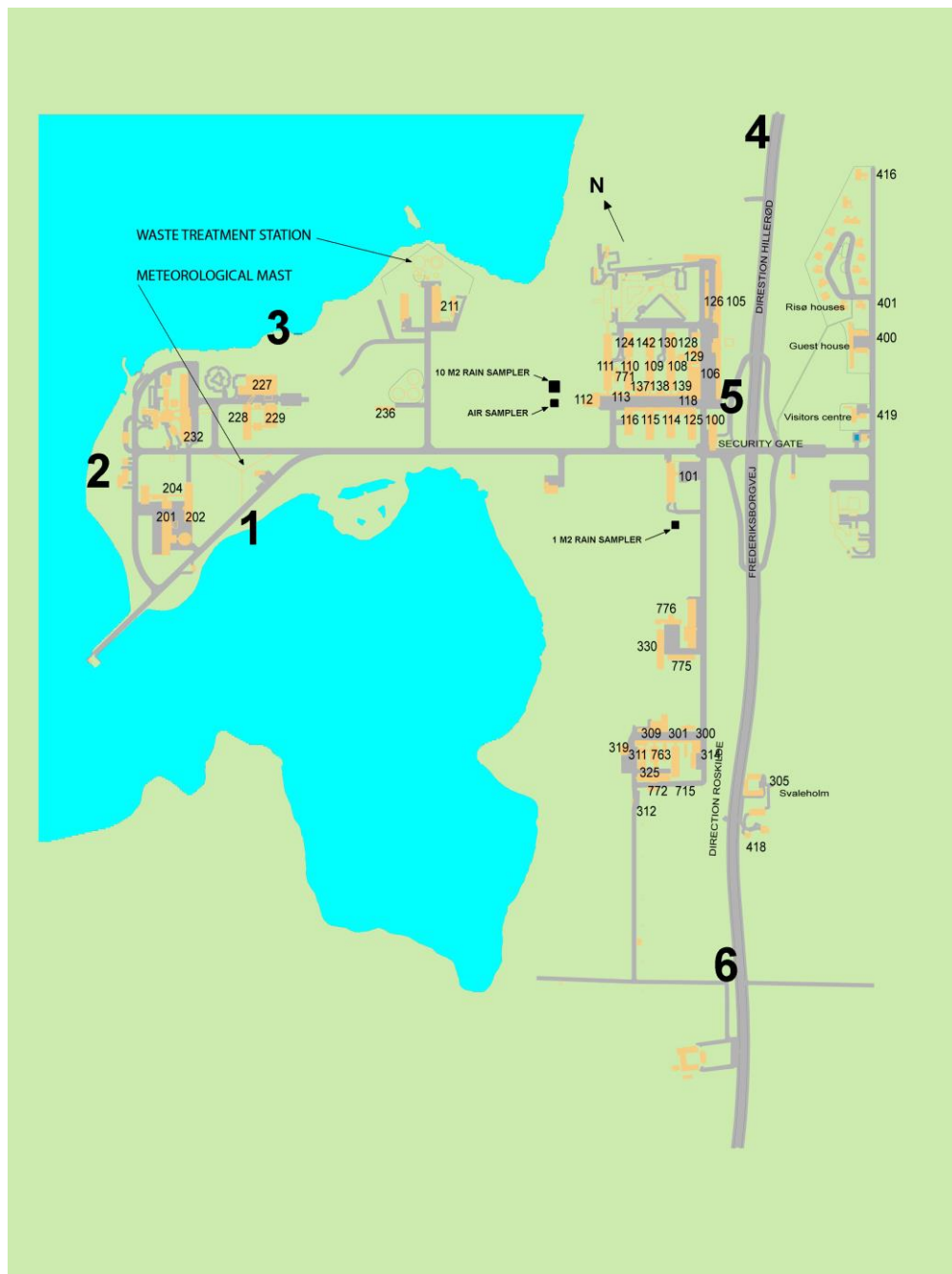


Fig. 8.1. Locations (1-6) for TLD measurements around the border of Risø (cf. Table 8.1).

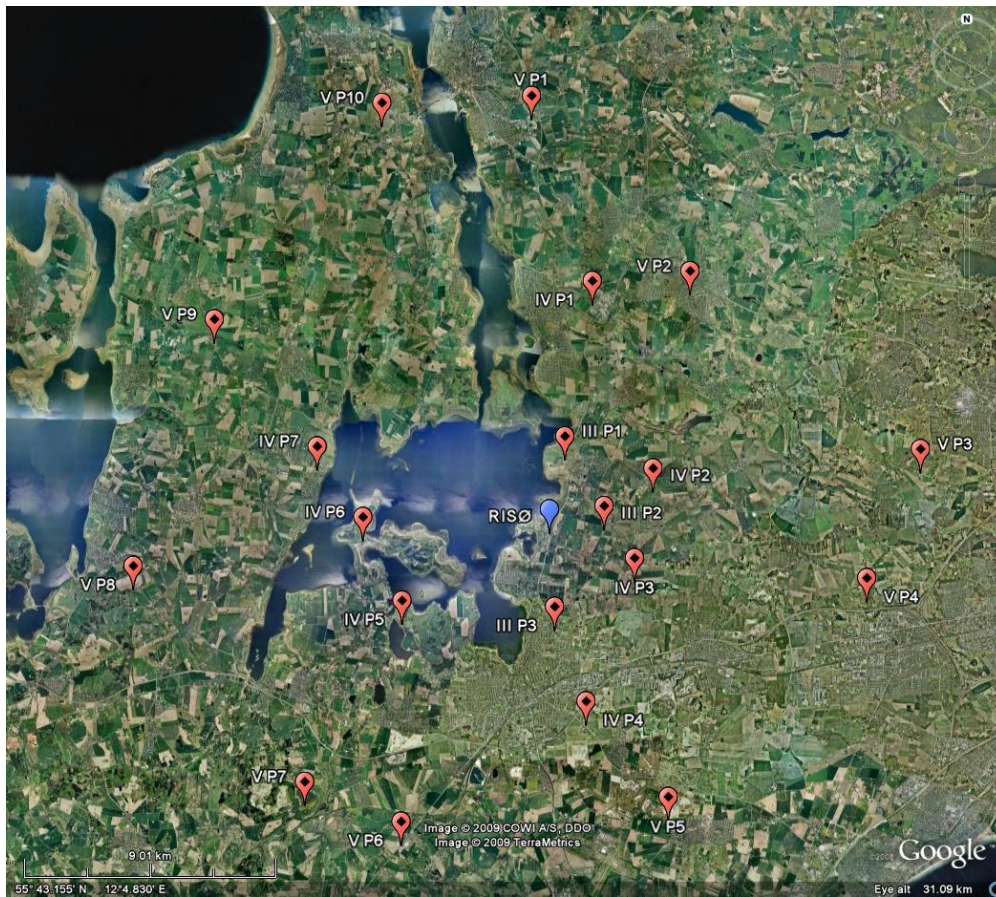


Fig. 8.2. Locations for measurements of background radiation around Risø in Zones III, IV and V.

MATERIALS AND METHODS

External gamma dose rate monitoring

Monitoring of external gamma dose rate is carried out with the following devices

- Thermoluminescence dosimeters TLD: LiF, measurement frequency annually from May to April. TLD equipment manufacturer: ALNOR/RADOS
- NaI detector: 3x3 inch, SAM 935 Surveillance and Measurement System, Berkeley Nucleonics Cooperation, USA, visual read-out

Calibration of TLD is carried out by irradiation of dosimeters at a calibration irradiator. Traceability of delivered doses is ensured through calibration of the dose rate of the calibration irradiator by the National Institute of Radiation Protection (NIS). Calibration has been verified by measurement with ionisation chamber from NPL, UK. The NaI detector is calibrated periodically vs. a Reuter Stokes high-pressure ionisation chamber.

Air sampler

The sampler at Risø is manufactured by DTU. Air is drawn through a polypropylene filter at a rate of about 2000 m³/h. The filter is normally changed weekly. The flow rate is monitored by a gas meter connected to a shunt. The gas meter reading is compared to that of a reference gas meter intermittently.

DTU analyse the filters by gamma spectrometry shortly after filter change to check for the presence of short-lived man-made radionuclides. The air filters are subsequently stored for a minimum of one week to allow for decay of short-lived naturally occurring radionuclides before repeated gamma analysis. Filters are analysed for ¹³⁷Cs, ⁷Be and ²¹⁰Pb and other gamma emitters.

Deposition collector

The Risø site operates a large rain collector of 10 m². The collector is heated and water is passed through an ion exchange column to a large tank. The 10 m² collector provides monthly samples of rain water analysed for tritium and ion exchange resin which is analysed by gamma spectrometry for ⁷Be, ¹³⁷Cs and ²¹⁰Pb and other gamma emitters.

Water and sediment

A waste water sample from the Waste Treatment Station is collected weekly and analysed for total beta radioactivity and the radionuclides ¹³¹I, ¹³⁷Cs and ²²⁶Ra. Water samples from Roskilde Fjord are collected each quarter and analysed for tritium, annually for ¹³⁷Cs. A sediment sample is collected annually from Roskilde Fjord and analysed for ¹³⁷Cs.

Terrestrial and aquatic biota and flora

Grass samples are collected weekly at the Risø site and analysed by gamma spectrometry. Samples are bulked to monthly samples which are analysed for ¹³⁷Cs.

Seaweed samples are collected annually from Roskilde Fjord at Risø and analysed for ¹³⁷Cs.

Sample reception and preparation

Sample identification numbers are entered in log books. Sample preparation methods include drying, freeze drying, ashing, sorting and sieving. Selected samples are archived.

Sample measurements

Radioactivity in samples is measured by total beta counting and gamma spectrometry.

Measurement devices

- Ge detectors for gamma spectrometry. Calibration of detectors is based on mixed-nuclide standards used occasionally. Monthly checks are made of detector efficiency and energy resolution. Background measurements of gamma systems are made a few times per year.
- Low-level Geiger-Müller counters for total beta counting, manufactured by DTU. Calibration based on standards of KCl. Counting efficiency and background are checked monthly.
- Liquid scintillation spectrometer for analysis of tritium in water. Samples are analysed with a calibration standard.

Analytical results, data handling and reporting tools

Analytical results are printed on paper, recorded in log books and stored in a data base on intranet. Results below detection limits recorded as such. Spreadsheets are used for calculating results from raw data.

Quality assurance, laboratory accreditation and intercomparison exercises

Analytical results are checked by experienced staff and discussed with senior scientists if questions arise.

DTU is accredited to testing for radioactivity by DANAK according to the international standard ISO 17025. The accreditation covers testing for certain non-gamma emitting radionuclides but not for radionuclides occurring in the environment and food in general.

DTU participate regularly in international intercomparisons on laboratory analyses of radionuclides.

CONCLUSIONS

This report shows the results of the environmental surveillance monitoring programme carried out at and around the Risø site in January-June 2015. The mean concentrations in air were: $0.23 \pm 0.18 \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.19 \pm 0.91 \text{ mBq m}^{-3}$ of ^7Be and $0.13 \pm 0.05 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 S.D.). The depositions by precipitation at Risø in the first half of 2015 were: $0.054 \pm 0.015 \text{ Bq m}^{-2}$ of ^{137}Cs , $433 \pm 43 \text{ Bq m}^{-2}$ of ^7Be , $22.5 \pm 4.5 \text{ Bq m}^{-2}$ of ^{210}Pb and $< 0.5 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as 63 nSv h^{-1} compared with $56 \pm 3 \text{ nSv h}^{-1}$ (± 1 S.D.) in the four zones around Risø. None of the recorded levels of radioactivity and radiation have given rise to concern. A number of samples for June have not yet been analysed due to illness, but the results will be reported in the next biannual report.

Center for Nuclear Technologies is Denmark's national competency center for nuclear technology. With roots in research in the peaceful use of nuclear power, DTU Nutech works with the applications of ionizing radiation and radioactive substances for the benefit of society.

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